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Inducing Extraseasonal Breeding in Goats and Sheep by Controlled Lighting

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INTRODUCTION

Soon after the discovery of the effect of light and darkness on the blooming and production of seed in plants by Garner, Allard, and others in the early 1920's, similar investigations were begun with animals. Bissonette (*1*)[2] has reviewed much of this early work. It was observed that most sheep, deer, and goats breed during the period of decreasing daylight; ferrets, starlings, juncos, turkeys, and many birds breed during the period of increasing daylight; and other species such as guinea pigs, guinea fowls, ground squirrels, and others showed little or no reaction to day length as regards their period of breeding. Bissonnette (*2*) succeeded in breeding Toggenburg goats in July after having had them on a reduced light schedule from April 5 to July 5. The control group showed absence of estrus from March 15 to September 1. During the last 4 or 5 years, geneticists have shown renewed interest in this subject, especially in its practical applications in animal breeding practices and management.

Yeates (*20*) observed that the natural breeding season of highly fertile crossbred ewes commenced in September, 10 to 14 weeks after the longest day. In the absence of pregnancy, estrus recurred at intervals of 16 to 17 days up to about the end of March, or 10 to 14 weeks after the shortest day. A group of similar sheep subjected to artificial illumination by electric light so that their daily hours of light rose gradually from 13 hours in mid-October to 21 hours by the end of January, ceased breeding 10 to 14 weeks following their shortest day, which was in mid-October. The same group, having

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[2] Italic figures in parentheses refer to Literature Cited, p. 15.

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their hours of light gradually reduced from 21 on the last of January to 14 by March 21 and maintained at this level until near the end of June, commenced breeding about May 20. Further investigations by Yeates (*21*) confirmed his earlier results. Responses occurred irrespective of the level at which the changeover of daily lighting occurred. There also was an apparent effect of light on the fertility of the rams.

Hart (*8*) produced out-of-season estrus in ewes by light rhythms of 4 hours of light and 8 hours of dark, twice during the 24-hour day, and also rhythms of 4 hours of light, 2 of dark, 4 of light, 14 of dark. All the ewes came into estrus under both treatments. The speed of response was governed by the period of anestrum reached before the animals were subjected to the light treatment. Moule (*11*) found that the sexual activity of rams was increased by reducing the hours of light 3¾ hours over a period of 6 weeks. Control rams showed no interest in ewes which were in estrus. Hafez (*3*, *4*, *5*, *6*) has investigated extensively the effect of controlled lighting on the breeding reactions of several types of sheep. He determined that the length of breeding season and the number of estrous cycles during the breeding season are influenced by the latitude of the place of origin of the breed. Those breeds which originated nearer the equator have a longer breeding season. They also have a shorter time-lag reaction to light treatment than those originating nearer the poles. Previous light treatment, through its residual effects, may control the maintenance and cessation of the sexual season. The ratio of darkness to light and the light rhythm may control the speed of response. Young animals are more readily influenced by the light treatment than adults, but the sexual season of lambs is only about one-fourth to one-third as long as that of adults. The onset of sexual activity varies with the time of birth and with the weight of the lambs. Once the sexual season has started, it continues with estrus at regular intervals so long as the daylight-darkness environment is favorable.

Robinson (*15*) is of the opinion that anestrum is a relative, rather than an absolute quiescence of sexual activity. Thus in the Merino breeds, which originated nearer the equator, a slight increase in pituitary activity stimulated by slightly shortened hours of daylight, will elevate it above the threshold for ovulation. A much greater stimulation is necessary for the Scottish and British breeds, which originated farther north. Terry and Meites (*17*) placed Rambouillet and Shropshire ewes in pens, one group in constant light, another in constant darkness, and a third in normal light conditions between June 22 and August 29. Rams were rotated every 2 days between the 3 groups. Lambing dates were not advanced for those in the pen under normal light, 1 ewe lambed earlier in the pen under constant darkness, and 4 lambed earlier in the pen under constant light. This indicates that continuous light may also stimulate reproductive functions.

Investigations of the effect of light on reproduction in other animals confirm the results observed in sheep and goats and suggest that other factors also may be important. Hammond (*7*) in experiments with ferrets and minks mentions wave length, intensity, daily duration of light exposure, and day-to-day change and rate of change as possible factors in the response to light treatment. Ferrets came in estrus

after a latent period of several weeks when subjected to periods of 7 hours of light followed by 5 of darkness. Female minks and ferrets returned to daylight at the end of February became anestrous at the height of the normal breeding season in mid-March. Minks taken from daylight in midsummer and put on a constant short day began to molt and come into their winter coat and show estrus. Hart (*9*) regards the light-dark ratio, rather than the total daily quantity of light, the controlling factor in inducing estrus. In ferrets this ratio is 2:1. Jenner (*10*) found that egg laying in the snail, *Lymnacea palustris*, was a long-day response that could be maintained over a long period of time, and could be prevented indefinitely by short-day conditions. A short light period with the long dark period interrupted by short intervals of light acts as a long-day periodic response and stimulates egg laying.

In 1947 the Bureau of Animal Industry began an experiment with goats, and in 1948 introduced Karakul sheep, in an attempt to determine the effect of length of day on the estrous periods of these animals and thereby examine the possibilities of fall lamb production and summer breeding in goats to insure winter milk production. If the breeding of these animals could be controlled, it would be of great economic importance to the sheep and milk-goat industries.

MATERIALS AND METHODS

In April 1947, 40 does of the common American type were purchased in Florida and brought to Beltsville, Md. They varied in age from yearlings to 4-year-olds as determined by examination of their teeth. They also varied greatly as to size, general body conformation, and color; and some were horned, some hornless. Ten Toggenburg bucks and one wether, discards from the regular milk-goat project, were added to the experiment in May, when they were approximately 3 months old. Males and females were kept in separate pasture lots during the summer and fall. Thirteen of the does gave birth to 23 kids between April 25 and August 29, inclusive. On December 1, when the experimental groups were made up, 7 of the does and 1 buck had died, leaving 33 does, 9 bucks, and 1 wether to begin the experiment. Three groups of 11 does each, the groups as nearly matched as to age and weight as possible, were selected. Other Toggenburg does and bucks discarded from the milk-goat project, as well as animals born within the experimental groups, were added from time to time as the experiment progressed.

Four darkrooms, each 10½ by 30 feet, were so constructed that they would provide complete darkness. These were equipped with three 40-watt daylight-type fluorescent lights, 47 inches long, mounted on the ceiling, 1 near each end and 1 in the middle of the rooms. Automatic switches were installed in each darkroom to regulate the time the lights came on and off. In the fall of 1948 a fan was installed for ventilation through ceiling and end-wall ducts.

During the spring, summer, and fall the goats were on pasture except for such hours as they might be in the darkrooms in early morning or late afternoon. During the time when pasture was not available the goats were fed alfalfa hay and 1 to 1⅓ pounds of grain mixture per animal per day. This mixture consisted of 4 parts cracked

corn, 4 parts oats, 2 parts wheat bran, and 1 part linseed meal. Phenothiazine and copper sulfate were given frequently to check stomach-worm infestation. Beginning September 1, 1947, the animals were observed twice daily (at 9 a. m. and at 3 p. m.) for signs of estrus, a wether or buck being used for testing the does.

Of the 3 groups of animals made up on December 1, 1947, 2 groups were placed in darkrooms and the other in open pens in the same barn. The switches were set in the darkrooms so that there would be continuous light for a period of 14 hours (making use of the hours of normal daylight by opening the door of the darkrooms or by letting the goats outside in favorable weather) followed by a period of 10 hours of darkness. This schedule was followed until January 9, 1948, when the hours of light were increased to 18 per day followed by 6 of darkness, until March 25. From March 26 until August, the 2 light-treated groups had 6 hours of light and 18 of darkness.

About January 1, 1948, 13 Toggenburg does from the current milk-goat project were put in darkroom No. 3 with the same lighting schedule as those in darkrooms Nos. 1 and 2. A buck was put in the darkroom with the Toggenburg does on July 26, 1948, and replaced every 4 weeks by another buck. This continued until December 17, 1948. With the same grouping of animals as through 1948, darkrooms 1, 2, and 3 were set for 18 hours of light and 6 of darkness on December 18, 1948, and this schedule continued until March 31, 1949, when the lighting schedule was reversed until November 1. Bucks were placed with all groups on March 25.

For 1950 and 1951 the animals were regrouped so that those which had been in the darkrooms would be under normal seasonal lighting and those which had been used as controls would now come under controlled lighting. The lights were set for 18 hours from November 1, 1949, to February 1, 1950, when the light schedule was reduced to 6 hours, followed by 18 of darkness. Bucks were placed with the control group in November 1949, and with the light-treated groups on March 2, 1950. A fourth group of 10 does was withheld from breeding in the fall of 1949 and placed under normal lighting conditions. A buck was also placed with these on March 2, 1950, to determine if the delayed fall breeding would have any effect on their estrus and breeding in the spring. The only changes in procedure for 1951 were that the lighting schedule of 14 hours of light and 10 of darkness was started December 12, 1950, and then was reversed on March 23, 1951, at which time bucks were put with each group.

In each year beginning about the first of August after most of the does had conceived, the animals were placed under normal seasonal lighting until the experiment was again set up late in the fall.

In April 1948, grade Karakul sheep were added to the experiment. One group of ewes was placed in a light-controlled room with a ram; another group and a ram were held under normal seasonal lighting conditions. A ram was allowed to run with each group during the experiment.

RESULTS WITH GOATS

The average number of animals in the light-controlled and in the control groups for each year is shown in table 1.

TABLE 1.—*Average number of animals in experiment, by years*

Year	Goats			Karakuls		
	Light-treated	Control	Total	Light-treated	Control	Total
1948	34	18	52	12	22	34
1949	32	25	57	14	19	33
1950	23	31	54	16	21	37
1951	38	27	65	----------	4	4
Total	127	101	228	42	66	108

The main objective for the first year, beginning in September of 1947, was to study the frequency and duration of estrus. Only a few matings were made, most of which occurred unintentionally. Frequency of estrus was determined by the number of days elapsing between first observation of estrus for one period and the first observation for the next period. Two estimates of the average frequency of estrus were made because there was considerable variation in interval between observed estrous periods. The intervals ranged from about a week to sometimes 2 months or more. One estimate, 21.03 days, was based on the average of the actually observed intervals. In the other estimate such long intervals as 60 days were considered as three periods. Intervals shorter than a week were considered a part of one continuous estrus, since in several instances estrous periods of 5 to 6 days were observed. The average interval as estimated by this method was nearly the same as the first, 21.09 days. For 1948 a tabulation was made separately for intervals between estrous periods from January through April, and from May through December. Averages for these two periods were 20.68 and 21.18 days, respectively, the difference not being significant.

TABLE 2.—*April, May, and June conceptions compared with total conceptions for each year, 1948–51*

Year	Goats		Karakuls	
	Light-treated	Control	Light-treated	Control
	Percent	*Percent*	*Percent*	*Percent*
1948	7.14	0	0	8.33
1949	55.56	15.38	100.00	60.00
1950	51.85	9.76	100.00	53.57
1951	96.55	36.00	([1])	[1] 100.00
Percentage for 4-year period	59.43	16.35	85.71	44.68

[1] There were no ewes in the light-treated group for 1951, and only 2 ewes in the control group which had been held over from 1950.

The duration of estrus was determined by observing an animal's behavior when a buck was brought into the pen. Since observations were made at 9 a. m. and 3 p. m., 2 successive observations would be either 6 or 18 hours apart. Three observations, however, would always include a 24-hour period. Two estimates of duration of estrus were made here also. The first was based on estrus observed from September 1947 through March 1949. The full length of estrus was probably noted during this time as the animals were not intentionally allowed to mate, although a few matings did occur. From this estimate the number of successive observations for an estrous period averaged 3.14, making the average length of period about 37.7 hours. The average number of observations per estrous period during the experiment was 2.73, therefore the estimated average length of period is 32.76 hours. That this value is smaller is undoubtedly owing to the fact that most of the animals after April 1949 were mated when observed in estrus rather than being allowed to continue in estrus. The length of estrus in different months is shown in figure 1. The average for the whole period except for June and July follows closely that for 1947–49, but at a lower level. Apparently the averages for June and July differed because the animals under the light treatment had longer estrous periods than those coming into estrus normally during this period of the year.

The number of estrous periods each month for the light-treated and the control groups, expressed as percentage of total periods observed in each group, is shown in figure 2. Estrous periods not actually observed, but known to have occurred because of the birth of kids, have been included in this calculation. They were determined by figuring back 150 days from the birth of the kids. This gives a reasonably close approximation of the date of occurrence of estrus.

Actual conceptions are shown in figure 3. Those conceptions in which the matings were not observed were determined by calculating back 150 days from birth of kids. No conceptions took place during January and February in the light-treated groups, which were under the long-day environment at this time. Beginning in March there was a sharp rise in number of conceptions until the peak, in May, by which time 53.76 percent of the kids born in the light-treated group had been conceived. A sharp drop to June, with fairly constant rate of conception at slightly above 5 percent per month, followed for the remainder of the year. The results from year to year as shown in table 2 were in fairly close agreement. The low numbers for 1948 are because few matings were made, those occurring being from unobserved heat periods. More than 3.5 times as many conceptions took place in the light-treated group as in the control group during the 3-month period, April–June.

The percentages of kids born dead and those dying before reaching 1 month of age were considerably higher among kids born from August through December than among those born from January through July. Nearly twice as many were born dead from August through December as during the first 7 months of the year, and one and one-half times as many died before reaching 1 month of age. Percentages of kids alive at 1 month, percentage dying when younger than 1 month, and percentage born dead are shown in figure 4. The percentage alive at 1 month of those born January through July was

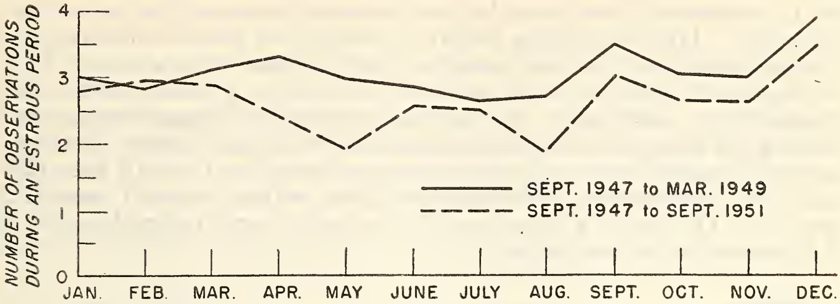

FIG. 1. AVERAGE DURATION OF ESTRUS IN GOATS AS CALCULATED FROM THE NUMBER OF OBSERVATIONS DURING AN ESTROUS PERIOD.

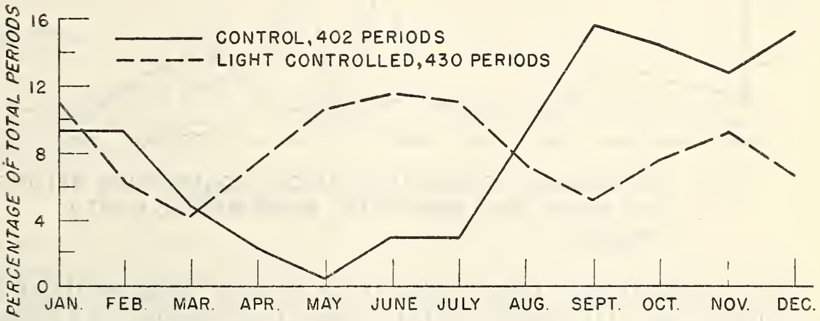

FIG. 2. OCCURRENCE OF ESTRUS IN GOATS, BY MONTHS, FOR THE DURATION OF THE EXPERIMENT.

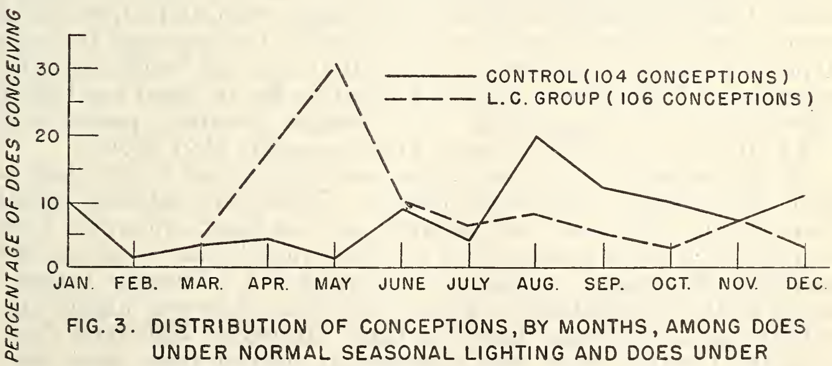

FIG. 3. DISTRIBUTION OF CONCEPTIONS, BY MONTHS, AMONG DOES UNDER NORMAL SEASONAL LIGHTING AND DOES UNDER CONTROLLED LIGHTING.

85.1, whereas of those born August through December the percentage was 76.3. Of those dying before 1 month the loss was 8.4 percent through July and for the remainder of the year 12.6 percent. Percentage born dead was 6.5 and 11.1 for the two periods of the year respectively. Mortality was greater among the Toggenburgs than among the goats of no particular breed, or "common" goats. Percentages of Toggenburgs and common goats alive after 1 month were 67.9 and 88.3, respectively. Percentages dying before 1 month were 17.4 and 7.3. Of the kids born dead, 14.7 percent were Toggenburgs and 4.5 percent were "commons."

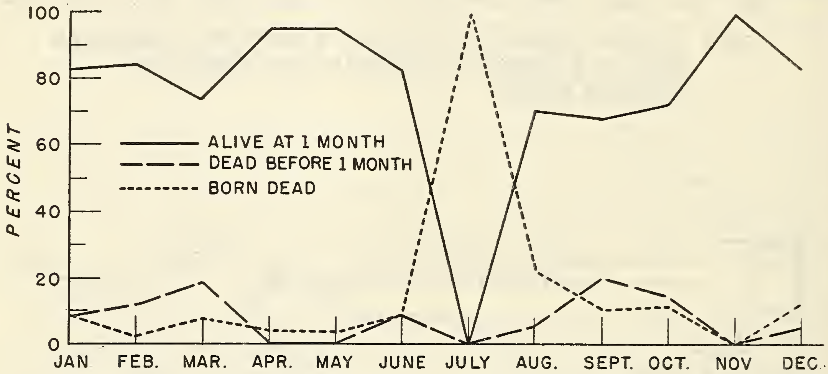

FIG. 4. PERCENTAGE OF KIDS ALIVE AT ONE MONTH, DYING BEFORE ONE MONTH, AND BORN DEAD, ACCORDING TO MONTH OF BIRTH.

Forty light-treated does kidded twice or more at intervals of 10 months or less. Of these, 2 kidded 4 times in succession and 7 kidded 3 times in succession with intervals averaging 7.5 and 7.6 months respectively. The average interval for those having only 2 successive parturitions within a 10-month period was 7.6 months. The average length of gestation for all pregnancies was 149.7±0.39 days. Differences in length of gestation due to month of mating were not significant. While the length of gestation for single, twin, and triplet births varied, the differences were not significant. The averages for each type of birth were 150.8±0.79, 149.5±0.50 and 148.7±0.96 days respectively. Difference in length of gestation due to breed was highly significant; for Toggenburgs the average gestation period was 152.1±0.74 days and for common American goats 148.7±0.40.

Weight at birth of kids born alive was investigated in its relationship with several influencing factors. Differences between breeds were highly significant, and between sex and month in which born significant at the 5-percent level as determined by the *t* test and by analysis of variance methods. The difference in weight between sexes in the Toggenburgs was not significant, but was highly significant in the common American type. Moreover, kids born from January through June were significantly heavier than those born from August through December. Average birth weights and standard errors are given in table 3 for breed, sex, and season of the year.

Number of kids born at a parturition may have an influence on the birth weight. Mean weight of kids born, regardless of sex or breed, was 5.53 pounds for single births, 4.92 for twins, and 4.21 for triplets. The differences are highly significant. There was a difference between the Toggenburgs and "commons" in percentage of different types of pregnancies. For the Toggenburgs the averages were 55.6, 38.9, and 5.5 for singles, twins, and triplets, respectively. For the "commons" the respective percentages were 31.3, 56.6, and 12.1.

TABLE 3.—*Birth weight of goats born alive as influenced by breed, sex, and season of year when born*

Breeding	Males		Females		Breed average		When born: January–June		When born: August–December	
	Ave.	E [1]	Ave.	E [1]	Ave.	E [1]	Ave.	E [1]	Ave.	E [1]
Toggenburg	6. 02	0. 16	5. 70	0. 15	5. 85	0. 13	5. 91	0. 19	5. 77	0. 18
Common	4. 90	. 10	4. 37	. 09	4. 67	. 09	5. 14	. 11	4. 11	. 11
Average	5. 23	. 11	4. 88	. 11	-----	-----	5. 40	. 10	4. 67	. 12

[1] E=standard error.

RESULTS WITH KARAKULS

Periods of estrus were not observed in the Karakuls. Ochre was smeared on the rams' breasts and the rams were allowed to run with the ewes. A paint mark on the ewe's back indicated that mating had taken place. Figure 5 shows the percentage of conceptions by month

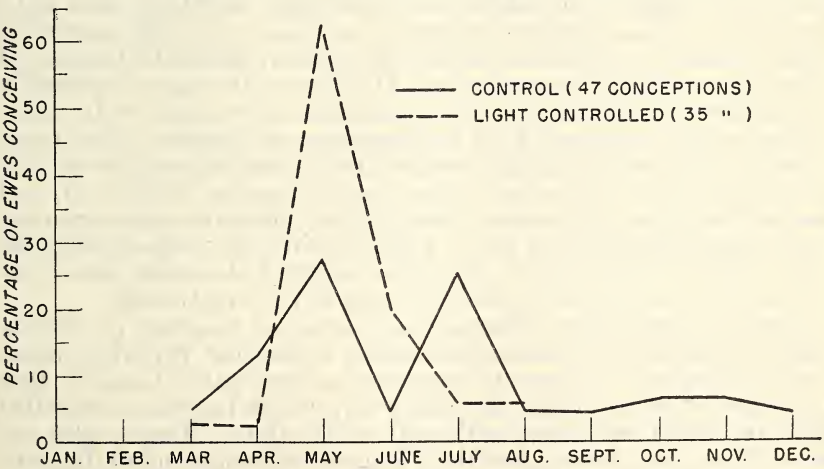

FIG. 5. THE PERCENTAGE OF ANIMALS CONCEIVING EACH MONTH IN THE LIGHT-TREATED AND IN THE CONTROL GROUPS OF KARAKUL SHEEP. (Percentage based only on animals which lambed.)

for the light-treated and control groups respectively, and table 2 shows the percentage that conceived in April, May, and June during each year of the experiment. The majority of conceptions occurred in May and July in the group held under normal lighting conditions. Over 60 percent of the conceptions in the light-treated group took place in May, and most of the remainder in June.

Births in both groups were concentrated from August through December, with a few in January. There was a significant difference, however, in birth weight in the control and light-treated groups in favor of the controls. There was no significant difference in birth weight between the sexes, but birth weights of single lambs were significantly higher than those of twins, the average difference being 1.4 pounds per animal. The percentages of single and twin pregnancies were 87.7 and 12.3, respectively. Only one lamb was dead at birth. Since none of the lambs were kept more than a few days, there is no data on postnatal mortality.

DISCUSSION

The results obtained in this experiment are in close agreement with those of other workers who have used controlled hours of light and darkness to produce out-of-season breeding in sheep and goats. The long-day period began about December 1 in most of the years covered by the experiment. In the 3 months following there was a decrease in the number of estrous periods. Presumably this was a result of the approach to the end of the natural breeding season, as the normal group also showed this decrease to some extent. In April there was a marked increase in estrous periods in the experimental group of does, and this rise continued until it reached its peak in June. In the meantime, the control group continued to show fewer indications of estrus and reached their minimum in May. A sharp rise did not occur until August, the beginning of the normal breeding season. It reached its peak in September, and continued at a high level until December. The occurrence of estrous periods in the light-controlled group reached a minimum during September, probably because of a high percentage of pregnancies. The rise in November is probably due to does which did not become pregnant in summer, or to estrus of does which produced kids in September or October. The onset of estrus as a result of light control took place approximately 1½ months after the beginning of the short-day period (March 1), and reached its maximum in June about 90 days following the beginning of the experimental short day. This is within the range of response reported by Yoshioka et al. (*22*) who reported that most does came in heat 70 to 80 days after the beginning of the experiment.

Hart (*8*) attributed differences in period of response of Suffolk sheep to the state of anestrum reached before the period of short daylight began. His group beginning on controlled light in May responded in 22 to 30 days, and the group which began on controlled light in March responded within 91 to 117 days. Yeates (*20*) observed that sheep having had their longest day at the end of January commenced breeding May 20 and were in their maximum breeding state about June 10 under reduced hours of lighting. The results of Yoshioka, Hart, and Yeates seem to agree in that the animals reached

their maximum breeding season in May and June, and the time elapsing between reduced hours of exposure to light and estrous reaction shortened as the animals get deeper into anestrum. Our own results do not differ materially from these. However, in 1950, the year in which the short day began nearly 2 months earlier than in the other 3 years of the experiment, the maximum period of estrus was a month earlier. This may not be significant since in 1948 the maximum period of estrus was nearly 2 months later than it was in 1949 and 1951. The period of short day began at practically the same time in the 3 years mentioned. Periods of long and short lighting and month of maximum estrus are summarized in table 4.

It appears from this summary of data that the fall estrus of those having had induced summer estrous periods is dependent on the time of the summer estrus, and occurs about 6 months afterwards. In animals that became pregnant during late spring or early summer, fall estrus began about 1 month after kidding.

The high percentage of conceptions from April through June in 1951 (table 2) may be due to two causes: (1) 26.8 percent of the animals in the group under controlled light and 38.7 of the group in normal light were 18 months of age or under and had not been used in the experiment before; (2) in the group under controlled light, 39 percent of the animals had received the same treatment the previous year (1950). In the control group, 22.6 percent had been under controlled light in 1950. This may correlate with Hafez's (*4*) statement that previous light treatment may control maintenance and cessation of the sexual season through its residual effects. It is not known, however, whether the residual effects would carry over for a year. If young animals are more responsive than older ones, the 26 percent of young animals in this group might also have had an appreciable effect on the results. Unless the time of birth has an influence on the time of first estrus, this would not seem to account for the high percentage of the control group which bred from April through June. One-fourth of the young animals in the control group had been born the previous fall (1950) and were approximately 6 to 7 months of age when bred in the spring of 1951. Records show 2 does which were in heat at 3 and 4 months of age respectively, and 2 others bred when 4 months old and a third at 8 months. The latter three produced kids in September and October. Results with the Karakuls were not so marked, although a large majority of conceptions (66 percent) in the light-treated group occurred in May. In the control group there were more than 50 percent of conceptions in May through July, with slightly more than 5 percent taking place each month until into December.

This seems to be in contradiction to the results of Schott et al. (*16*) and Phillips et al. (*13*), but agrees with results reported in Uzbekistan (U. S. S. R.) by Pomanskii and Stojanovskaja (*14*). They observed that Karakuls may breed all the year. The present results covered a period of 4 years, but there was wide variation, ranging from only slightly over 8 percent of conceptions occurring from April through June in 1948 to 100 percent in 1951 (only 2 animals). However, the results for 1949 and 1950 of more than 50 percent of conceptions from April through June indicate a rather wide breeding range.

TABLE 4.—*Length of long and of short periods of light and their effect on the estrous periods of goats*

Year	Date animals were put on long days of light	No. of hours out of 24 that animals were kept in light	Date animals were put on short days of light	No. of hours out of 24 that animals were kept in light	Month of maximum induced estrus	Month of maximum natural estrus following period of induced estrus
1947–48	Dec. 1, 1947	14	Mar. 25, 1948 [1]	6	July	January.
	Jan. 9, 1948	18				
1948–49	Dec. 17, 1948	18	Mar. 31, 1949	6	May	November.
1949–50	Nov. 1, 1949	18	Feb. 1, 1950	6	April	October.
1950–51	Dec. 12, 1950	14	Mar. 23, 1951	10	May	

[1] From about Aug. 1 until they were put on long periods of daylight in the fall, the animals were under normal seasonal lighting conditions.

Perhaps the Karakuls were not a satisfactory breed for this experiment because of their naturally more widespread breeding season. If Merinos or the Down breeds of sheep had been used, it is possible that the results might have been more pronounced and more in agreement with those of Hafez (*5*), Yeates (*20*), and others. Our estimate of the duration of estrus for the goats, as observed in this study, was probably more accurate for the period September 1947 through March 1949 than for the whole period of the experiment, since during this time the periods were not cut short by mating of the animals in estrus. The average for the 19-month period mentioned was 37.7 hours, or approximately 1½ days. There was great individual variation, however, ranging from less than 6 hours to nearly a week. Does with extremely long estrous periods were usually poor breeders. Estrus recurred on an average of 21 days. This agrees with the results reported by Phillips et al. (*12*). Their results also showed wide variation in estrous pattern between individuals.

Most of the animals were very regular, 1 interval varying from another by only 1 or 2 days. Other animals were very erratic, having periods only 5 or 6 days apart once or twice and then perhaps returning to the normal interval of 17 to 22 or 23 days. Still others had long intervals which were multiples of 17 to 22, suggesting the occurrence of unobserved periods of estrus. Whether estrus was of only a few hours' duration and escaped observation or whether it did not occur at all is not known.

This raises the question of how the light-dark ratio brings about out-of-season estrus. During the so-called anestrous period, is there absolute inactivity of the pituitary gland and ovaries, or do short unobserved estrous periods occur? If there is absolute inactivity, then the decreasing ratio of light to darkness must stimulate the pituitary gland to renewed activity and bring about recurrence of estrus. On the other hand, if there is a certain amount of pituitary activity at all times, it may be assumed that activity during anestrus is below the threshold necessary to produce perceptible estrus, but as the ratio of light and darkness changes, activity reaches and passes this threshold and visible estrus results. Thus it would appear that increased darkness merely stimulates pituitary activity to a higher level so that estrus is prolonged and visibly recognizable. The fact that several goats under normal conditions bred during the summer seems to support the idea of continuous ovarian activity. Robinson (*15*) and Watson (*19*) also incline to this opinion. Another point in support of this theory is that the duration of estrus through May, June, and July averaged 33 hours as compared to 39 hours for the remaining months of the year.

The performance of goats under conditions in the Philippines, as reported by Villegas (*18*) may also help to explain the results. He reported the length of estrus to vary from 18 hours to 3 or 4 days. In the tropical climate of the Philippines (between 5° and 19° N. latitude) the hours of daylight are not so variable throughout the year as in the United States, the southernmost point of which is about 25° north latitude.

Villegas (*18*) states that goats will breed throughout the year, but conceptions are most numerous in May, June, and November. The

estrous cycle was reported at 10.2 days which is only one-half that observed at Beltsville. Gestation averaged 148.1 days or about 1.5 days shorter than at Beltsville. It is possible that the more nearly equal length of day and night in the Philippines shortens both duration of estrus and time between periods. This agrees with the observation of Hafez (*3*, *5*). The return of first estrus after parturition in the fall at Beltsville was 2 to 3 months. This would occur at the height of the normal breeding season, whereas in the usual spring kiddings, does would be approaching their normal anestrous period. In the Philippines the return of estrus following parturition was 91.5 days, or approximately 3 months. Conditions of management, which were not stated, might have been a factor. At Beltsville the kids were allowed to nurse the dam until 4 to 6 months of age. In several cases where the kid was dead at birth or died soon after, the dam came into estrus in about a month.

Length of gestation for the goats was not affected by out-of-season breeding, the average difference between fall-bred and spring-bred does being only 0.06 day. The average of 149.7 days was 0.5 day less than for the dairy herd at Beltsville for the 4 years, 1948–51, inclusive. This probably is due to the presence in the herd of "common" goats, which have a slightly shorter gestation period than the Toggenburgs.

The lighter birth weight and the higher mortality of goats born from August to December, inclusive, suggests some unfavorable influence at work for does bred and young produced out of season. The birth weight of the Karakul lambs born out of season was also lower than for those born in the normal season. It is not yet known what factors bring about the lower birth weight in out-of-season lambs.

The effect of extraseasonal breeding of goats on volume of milk produced and length of lactation was not determined, as the kids were allowed to nurse the does. It is also not possible to conclude whether the expense of darkrooms, electricity, and management would be sufficiently offset by added production of winter milk or fall lambs to make the practice of out-of-season breeding commercially practical. The experiment is conclusive, however, in showing that the dark-light ratio is an important factor in determining the breeding season of sheep and goats, and that by shifting the ratio from its normal seasonal occurrence, the animals can be brought to breed at any time of the year desired. The intensity of darkness necessary to produce reaction was not studied.

SUMMARY AND CONCLUSIONS

Account is given of an experiment with goats and Karakul ewes to induce out-of-season breeding by artificially controlling the dark-light ratio.

Both species responded to the treatment, and 59.4 percent of the goats and 85.7 percent of the Karakuls subjected to controlled lighting bred during the months of April, May, and June. In the control group, the percentages breeding during these months were 16.4 and 44.7 for goats and sheep respectively.

The Karakul sheep has a wider range of breeding season during the year than goats.

The average interval between estrous periods for the goat was 21 days. There was no appreciable difference in the length of the interval between does coming into estrus at the normal time of year and those experiencing induced estrus in the spring.

The average duration of estrus was 37.7 hours. There was an indication that estrus occurring in the fall may last a few hours longer than that occurring in the spring. Length of gestation, however, was no different in spring-bred and in fall-bred does.

Birth weight of goats and lambs born in the fall was less than that of those born in the spring.

Mortality at birth and for one month thereafter was greater among fall-born kids than among those born in spring.

It can be concluded definitely that manipulation of the dark-light ratio will cause sheep and goats to change their normal breeding season.

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